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Atmospheric Chemistry and Physics Discussions

Interactive comment on "Effects of cosmic ray decreases on cloud microphysics" *by* J. Svensmark et al.

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In their comment the authors recognize that referring to deviations beyond 3 standard deviations is not in itself a measure of statistical significance. Their computation of the probability of having such an excursion in a sample of 121 random events, giving a 20.9% chance, is correct, and would be relevant if the signal were a Gaussian white noise (no autocorrelation). I also acknowledge that memory in the data will change this estimate, but as with the other statistical presented in the paper, there are underlying idealizing assumptions that are not met by this signal. It is, for instance not clear how to compute the autocorrelation (AC) function in an appropriate manner because of the strong seasonal and other non-stationarities.

In the following I will only deal with the signal for the optical thickness. The authors can

easily perform the same analysis on the other components or the principal component.

In my Fig. 1 I show in the upper left panel a detrended version of the signal obtained by performing a moving average with a window of 60 days, and then subtracting this moving average from the original signal. It looks like the seasonal correllations have been removed by this procedure, but by plotting the cumulative sum of the detrended signal (the lower left panel) it appears that there still are clear seasonal patterns that will influence the AC function. In the upper right panel I have detrended with a 20-day moving average. In the cumulative sum in the lower right panel the seasonal patterns are still discernible, but much weaker.

The AC functions corresponding to these different detrending procedures are shown in Fig.2. Obviously the stronger filter (20 days moving average) removes more of the long-range correlations. By application of Eq. (1) in the authors' comment, I find that kc= 2 for both AC functions (although kc=3) is near to satisfy the criteron to be included for the 60-days curve), and I find Neff=43.6 days, and a probability of reaching 3.1 sigma of 8% for 60-days filtering, and Neff=54.0 days, and probability of 10% for 20-days filtering. However, it should be emphasized that the conditional averaging for the optical thickness in the discussion paper does not reach 3.1 sigma, but rather 2.5 sigma. The probability of this correlated noise reaching the observed 2.5 sigma is considerably higher, 24% and 29%, respectively.

However, it is not necessary to employ these theoretical estimates to assess these probabilities, since they can be obtained directly from the detrended time series. In Fig.3 I have computed the minimum value of the 20 day detrended optical thickness in a moving 120-day window as a function of time. The gray horizontal line marks 2.5 sigma. In as many as 34% of these windows the signal goes beyond 2.5 sigma. I leave it to the authors to apply this procedure to the principal component and compute the probability for exceeding the 3.1 sigma limit.

A feature that is quite apparent from Fig.3 is the clear non-stationary pattern (partly seasonal) in the extreme values. It is a symptom that not only the local mean signal is subject to seasonal and other non-stationarities, but also the fluctuation level around this mean. Large deviations attributed to Forbush decreases may well be due to that this decrease has occured during a season with high fluctuation level.

These non-stationarities also shed further doubt on the significance of the correlations claimed in Fig.2 in the discussion paper. The null hypothesis tested by the students t-test is that there is no correlation, only i.i.d. Gaussian noise. The noise levels present at the time of different Forbush events are probably not identical to each other.

Interactive comment on Atmos. Chem. Phys. Discuss., 12, 3595, 2012.

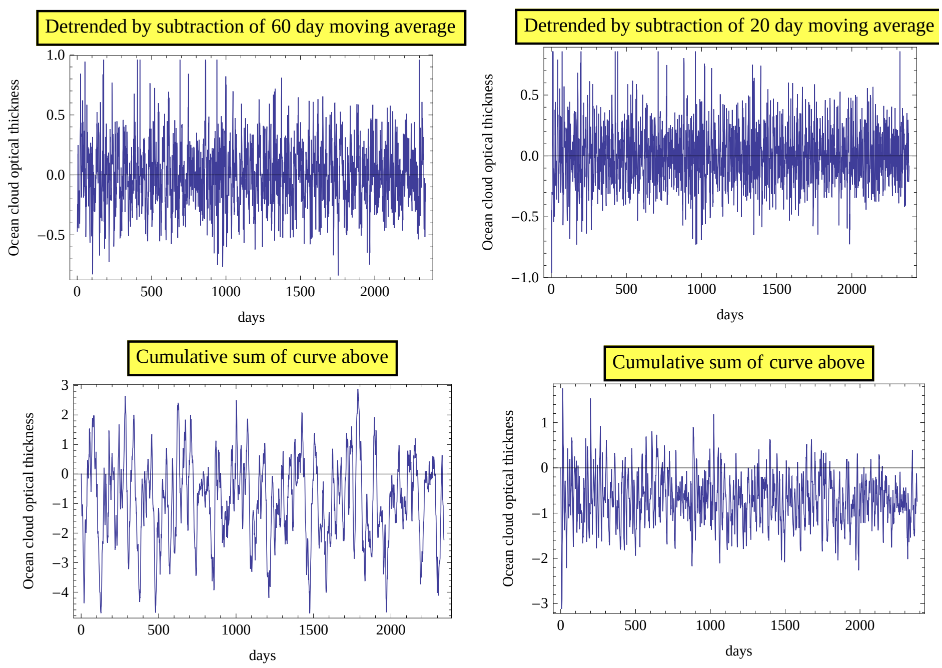

Fig. 1. Upper left panel: optical thickness detrended with 60-day moving average. Upper right: The same with 20-day moving average. Lower left and right: the cumulative sum of the signal above.

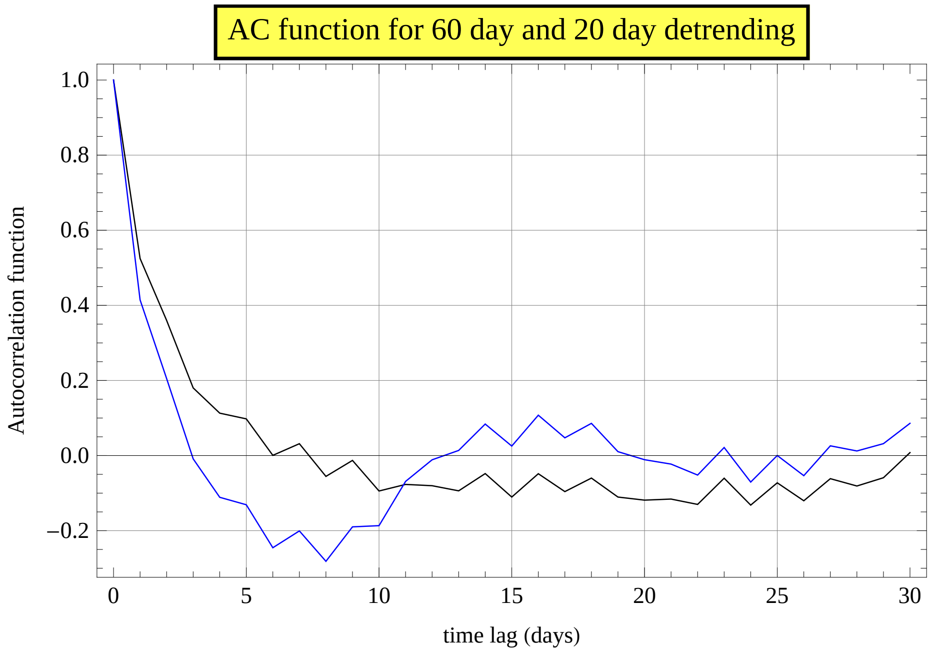

Fig. 2. Autocorrelation functions for signal detrended with 60-day moving average (black), and with 20-day moving average (blue)).

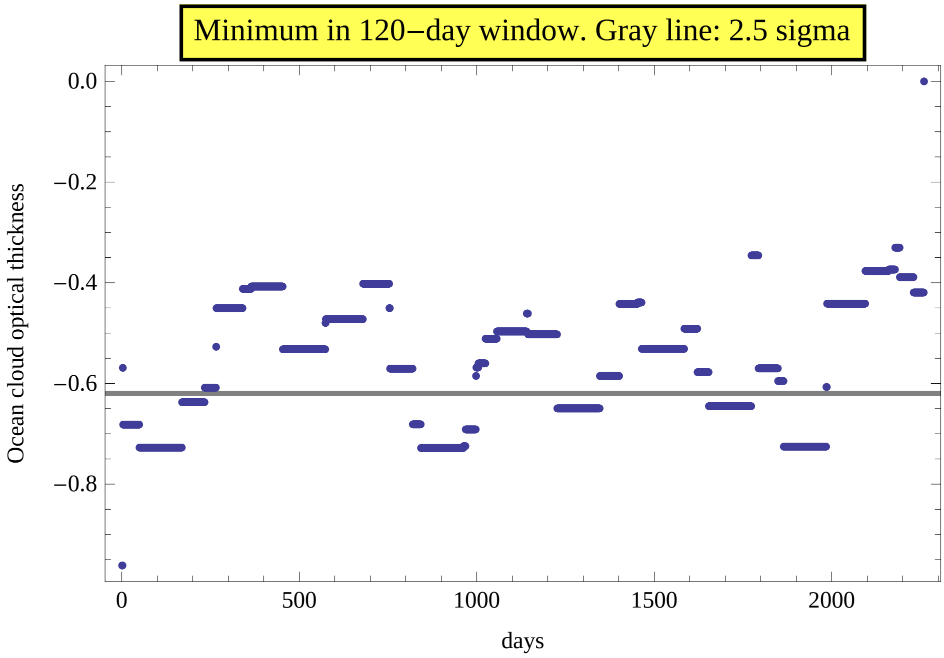

Fig. 3. Minimum value of the 20 day detrended optical thickness in a moving 120-day window as a function of time. The gray horizontal line marks 2.5 sigma.